US 20010045257A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2001/0045257 A1**

PEPIN et al. (43) **Pub. Date: Nov. 29, 2001**

(54) **CATHETER HAVING INTERLOCKING RIBBED BOND REGIONS**

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(*) Notice: This is a publication of a continued prosecution application (CPA) filed under 37 CFR 1.53(d).

(21) Appl. No.: **09/378,867**

(22) Filed: **Aug. 23, 1999**

Publication Classification

(51) **Int. Cl.**[7] **B32B 31/00**

(52) **U.S. Cl.** **156/158**; 156/304.5; 156/294

(57) **ABSTRACT**

A method of bonding a first tubular member to a second tubular member to form a catheter shaft. The method comprising the step of providing a first tubular member including a distal end, a proximal end, and a lumen extending between the distal end and the proximal end thereof. The method further including the step of providing a second tubular member including a distal end, a proximal end, and a lumen extending between the distal end and the proximal end thereof. The method further including the steps of inserting a joining portion of the first tubular member into a joining portion of the second tubular member and applying heat the joining portions.

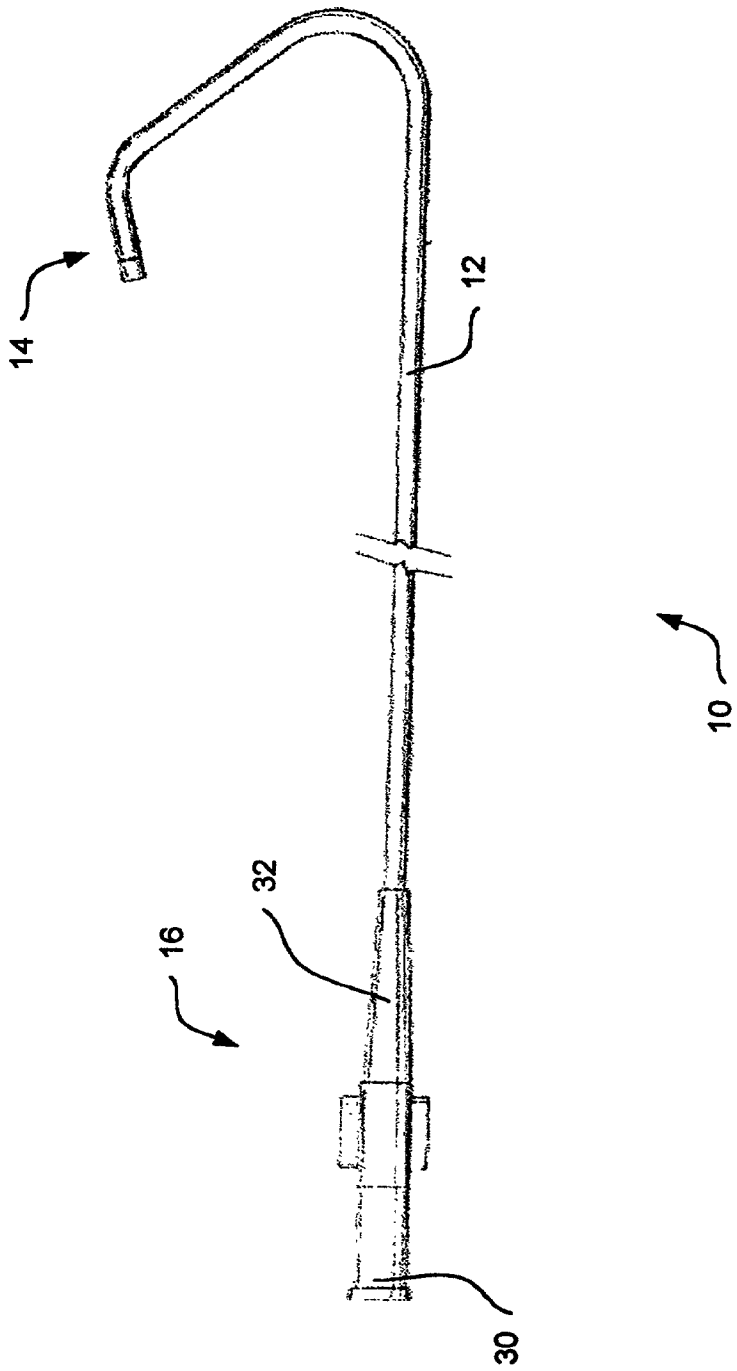


FIG. 1

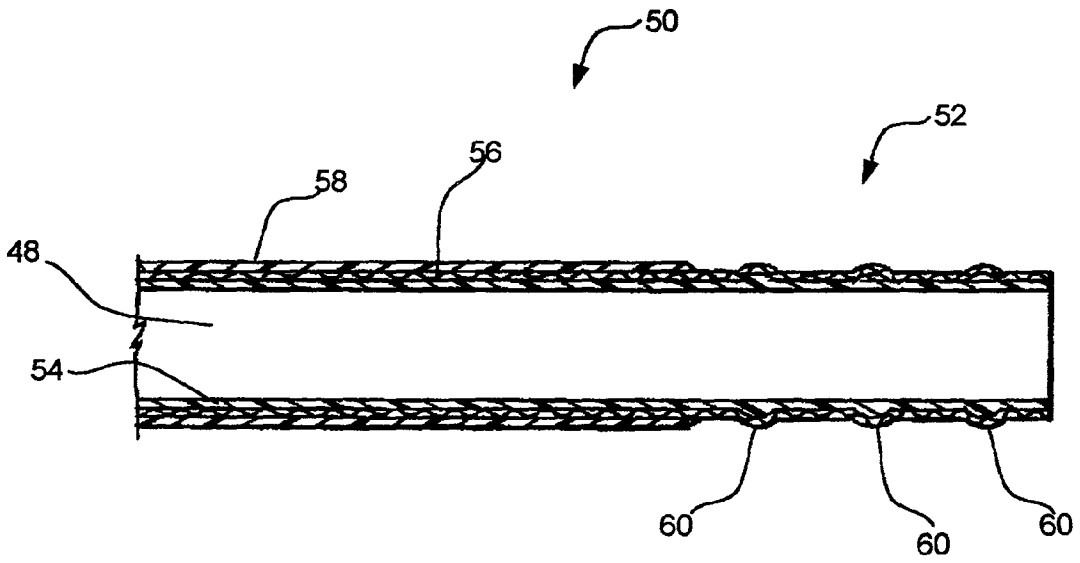


FIG. 2

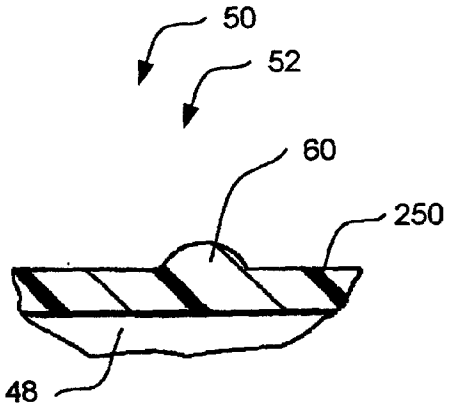


FIG. 3

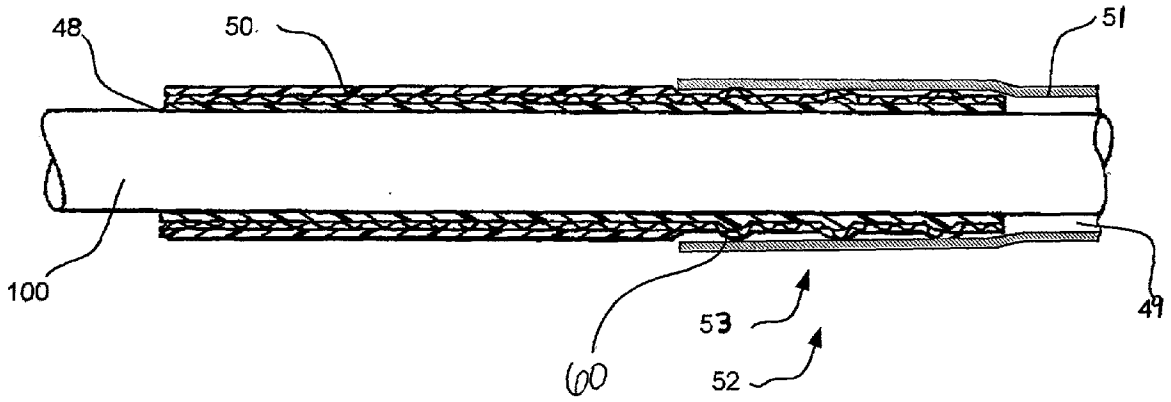


FIG. 4

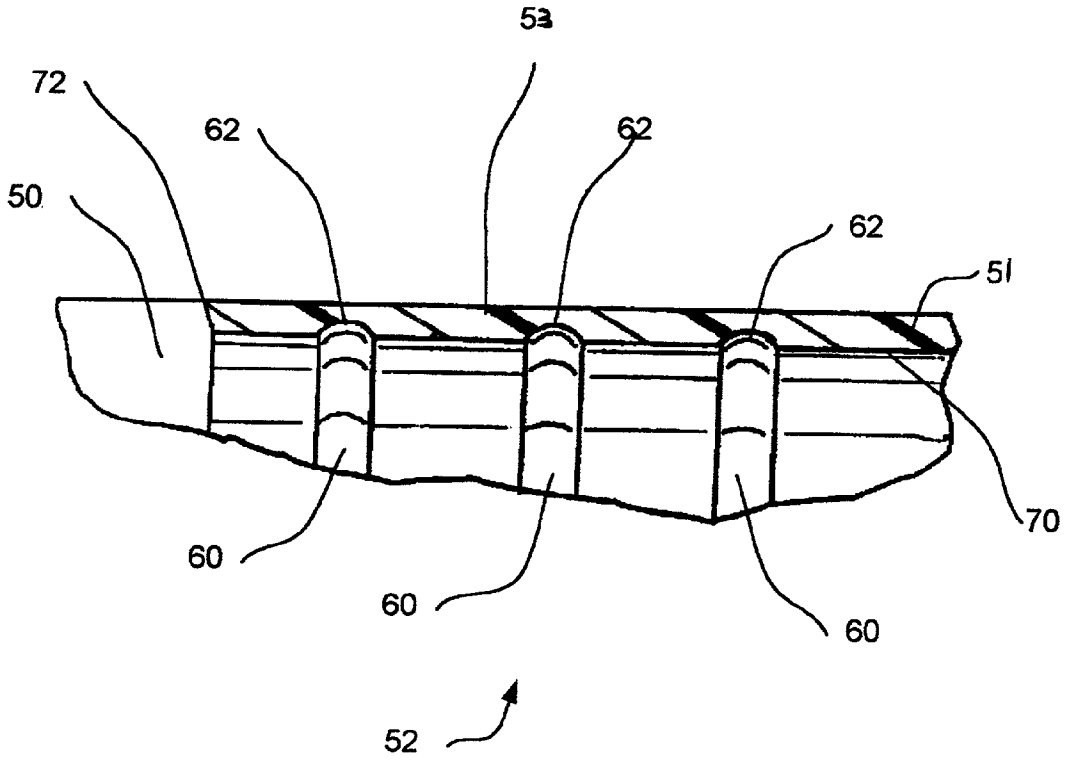


FIG. 5

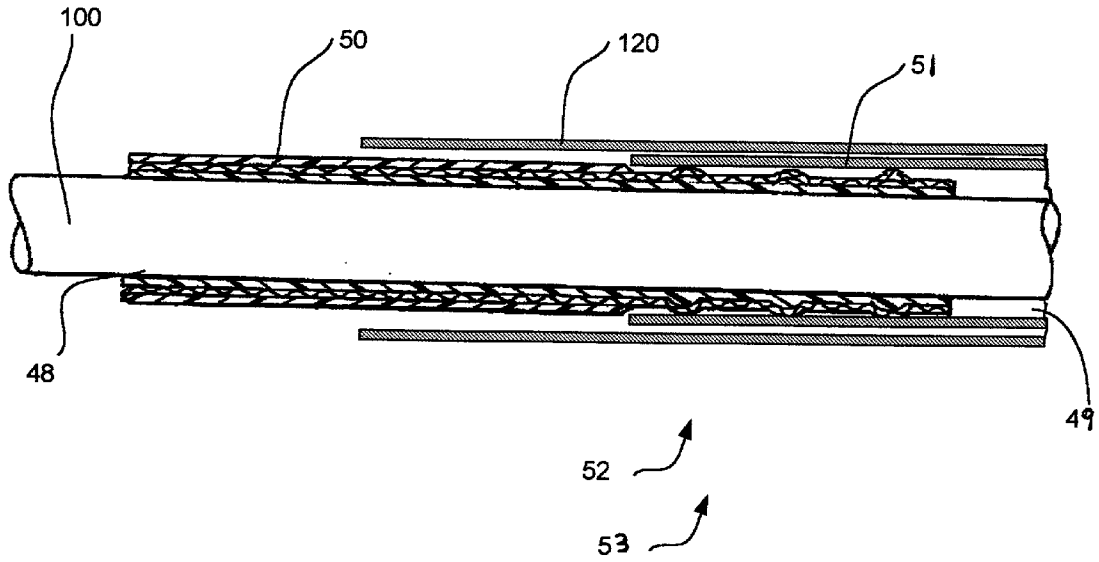


FIG. 6

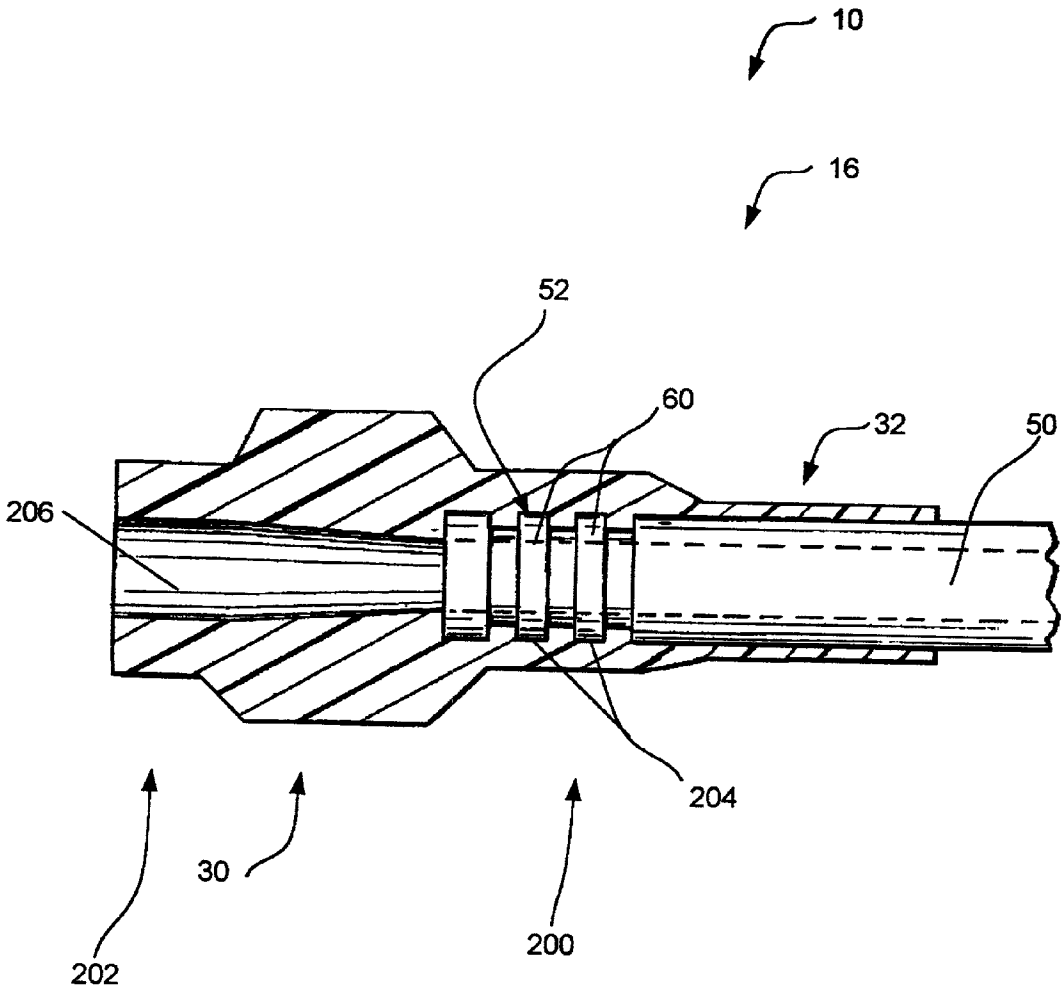


FIG. 7

CATHETER HAVING INTERLOCKING RIBBED BOND REGIONS

FIELD OF THE INVENTION

[0001] The present invention relates generally to catheters for performing medical procedures. More particularly, the present invention relates to guide catheters for use in angioplasty procedures.

BACKGROUND OF THE INVENTION

[0002] Intravascular diseases are commonly treated by relatively non-invasive techniques such as percutaneous transluminal angioplasty (PTA) and percutaneous transluminal coronary angioplasty (PTCA). These angioplasty techniques typically involve the use of a balloon catheter. In these procedures, a balloon catheter is advanced through the vasculature of a patient such that the balloon is positioned proximate a restriction in a diseased vessel. The balloon is then inflated and the restriction in the vessel is opened.

[0003] The most widely used form of angioplasty makes use of a guide catheter positioned within the vascular system of a patient. The guide catheter assists in transporting the balloon dilation catheter to the restriction in the diseased vessel. During this procedure, the distal end of the guide catheter is typically inserted into the femoral artery located near the groin of the patient. The guide catheter is urged through the vasculature of the patient until its distal end is proximate the restriction. In many cases, the distal end of the guide catheter is positioned in the ostium of the coronary artery. The balloon catheter may then be fed through a lumen in the guide catheter.

[0004] It is desirable that a guide catheter incorporate a level of rigidity which will allow it to be passed through the vascular system without folding or buckling. To assist in directing the distal tip of the guide catheter to the coronary ostium of the patient, the distal portion of the guide catheter may include one or more bends. The distal tip of the guide catheter is typically formed from relatively soft, flexible material to avoid trauma to arterial vessels, and allow flexing of the distal tip to aid the guide catheter in traversing desired arterial branches.

[0005] In some applications, it is desirable to form a guide catheter by bonding together two or more tubular sections in order to achieve a more rigid proximal portion and more flexible distal portion. It may also be desirable to have the distal portion of the guide catheter shaft be comprised of one or more tubular sections which are adapted to be formed into a curved shape. As described above, these curves aid in directing the distal tip of the guide catheter to the coronary ostium of a patient. In some embodiments, it is desirable to have a distal portion of the elongate shaft which can be heated and bent to a desired shape, then allowed to cool. By way of a second example, it may be desirable to include one or more tubular sections having a reinforcement braid, and one or more additional tubular sections having no braid. A braid or other reinforcement member is used to strengthen the tubular section and increase torque transmission. When a guide catheter is comprised of more than one generally tubular section, these sections are joined together at joints where the distal end of a first tubular section is affixed to the proximal end of a second tubular section.

SUMMARY OF THE INVENTION

[0006] The present invention relates generally to catheters for performing medical procedures. More particularly, the present invention relates to guide catheters for use in an angioplasty procedure. A guide catheter in accordance with the present invention includes an elongate shaft. A hub may be affixed to the proximal end of the elongate shaft and an atraumatic tip may be affixed to the distal end of the elongate shaft. The elongate shaft is preferably comprised of more than one generally tubular section.

[0007] A method of bonding tubular members in accordance with the present invention may begin with the step of forming a joining region on the distal portion of a first tubular member. The joining region preferably includes a plurality of ribs and a plurality of areas with a generally reduced diameter relative to the ribs. A variety of manufacturing methods may be used to form the ribs including material forming processes and material removal processes.

[0008] A method in accordance with the present invention includes the step of positioning a mandrel so that at least a portion of its length is disposed inside the lumen of the first tubular member. The joining region of the first tubular member is then inserted into the lumen of a second tubular member. After the joining region of the first tubular member is inserted into the lumen of the second tubular member, the mandrel will be positioned so that at least a portion of the length thereof is disposed inside both the lumen of the first tubular member and the lumen of the second tubular member.

[0009] The assembled tubular members are then subjected to heat and pressure proximate the joining region of the first tubular member. A number of methods may be used to heat the tubular members, including convection, conduction and radiation. The second tubular member is thus bonded to the first tubular member at the joining region.

[0010] Having formed a bond, the assembly is then allowed to cool. The assembly may be submersed in a relatively cool fluid to speed cooling of the assembly. Examples of fluids which may be suitable for some applications include water and air. Relatively cool air may also be impinged onto the assembly. After the catheter assembly has cooled, the mandrel may be removed from the lumen of the catheter assembly.

[0011] An additional method in accordance with the present invention includes the step of positioning a shrink wrap sleeve over both tubular members in an area proximate the joining region of the first tubular member. After the sleeve is disposed about the tubular members, heat is applied to joining regions to form a bond. At an elevated temperature, the shrink wrap sleeve applies the pressure necessary to form the second tubular member around the joining region of the first tubular member. Having formed a bond, the assembly is then allowed to cool. After the assembly has cooled, the sleeve and the mandrel are removed.

[0012] An additional method in accordance with the present invention may be used to bond a hub to a tubular member. This method typically begins with the step of forming a bonding region on the tubular member proximate the proximal end thereof. The bonding region typically includes at least one rib and at least one area of generally reduced diameter relative to the rib diameter. The proximal

portion of the tubular member is then positioned inside the cavity of a molding tool. Molten plastic is then injected into the cavity of the molding tool and allowed to cool.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1** is a plan view of a guide catheter in accordance with an exemplary embodiment of the present invention;

[0014] **FIG. 2** is a sectional plan view of a tubular member having a joining region form thereon depicting raised ribs and reduced diameter portions therebetween;

[0015] **FIG. 3** is an enlarged partial sectional view of a rib portion on a catheter shaft;

[0016] **FIG. 4** is a sectional plan view of the tubular member of **FIG. 2** with a second tubular member disposed over the joining region prior to bonding;

[0017] **FIG. 5** is a sectional plan view of a first tubular member which has been bonded to a second tubular member depicting the second tubular member conforming to the ribs and reduced diameter portions therebetween;

[0018] **FIG. 6** is a sectional plan view of the tubular member of **FIG. 2** with a second tubular member disposed over the joining region and a heat shrink sleeve disposed over the assembly prior to bonding; and

[0019] **FIG. 7** is a plan view of a hub assembly in accordance with an exemplary embodiment of the present invention incorporating ribs and reduced diameter portions on a joining region.

DETAILED DESCRIPTION OF THE INVENTION

[0020] The following detailed description should be read with reference to the drawings, in which like elements in different drawings are numbered identically. The drawings, which are not necessarily to scale, depict selected embodiments and are not intended to limit the scope of the invention.

[0021] Examples of construction, materials, dimensions, and manufacturing processes are provided for selected elements. All other elements employ that which is known to those of skill in the field of the invention. Those skilled in the art will recognize that many of the examples provided have suitable alternatives which may be utilized.

[0022] **FIG. 1** is a plan view of a guiding catheter **10**. Guiding catheter **10** includes an elongate shaft **12**, a distal portion **14**, and a proximal portion **16**. Proximal portion **16** of catheter **10** includes a hub **30** and a strain relief **32**. Hub **30** and strain relief **32** enable a physician to connect other devices to guiding catheter **10**. Hub **30** and strain relief **32** also provide a convenient place for a physician to apply longitudinal or rotational forces in order to manipulate guiding catheter **10**. Connected to the distal end of catheter **10** is a distal tip **20**. In a preferred embodiment, distal tip **20** is generally softer and more flexible than elongate shaft **12**.

[0023] Those of skill in the art will appreciate that for many applications of catheter **10**, elongate shaft **12** is preferably comprised of more than one generally tubular section **50**. For example, the distal portion of elongate shaft **12** may be comprised of one or more tubular sections **50** which are adapted to be formed into a curved shape. Curves disposed proximate the distal portion of elongate shaft **12** aid in directing the distal end of catheter **10** to the coronary ostium of a patient. In some embodiments, it is desirable to have a distal portion of elongate shaft **12** which can be heated and bent to a desired shape, then allowed to cool. By way of a second example, it may be desirable to include one or more tubular sections **50** having a reinforcement braid, and one or more additional tubular sections **50** having no braid. When elongate shaft **12** is comprised of more than one generally tubular section **50**, these sections are joined together at joints where the distal end of a first tubular section **50** is affixed to the proximal end of a second tubular section **50**.

[0024] **FIG. 2** is an enlarged sectional view of a preferred distal portion **14** of a tubular section **50** of the present invention having a joining region **52** and a lumen **48**. Tubular section **50** is comprised of an inner tube **54** which is overlaid by a support member **56**. An outer tube **58** overlays support member **56** and preferably terminates proximal to the joining region **52**. Joining region **52** of tubular section **50** includes a plurality of ribs **60** extending circumferentially around the shaft at spaced longitudinal positions. The joining region **52**, including the ribs **60** and axial spaces therebetween, preferably has a smaller outside diameter than the shaft proximal thereto. The ribs have a slightly larger diameter than the axial regions therebetween.

[0025] A variety of manufacturing methods may be used to form joining region **52** and ribs **60** of tubular section **50** including material forming processes and material removal processes. Examples of material removal processes which may be acceptable in some applications include turning on a lathe and centerless grinding. An example of a material forming process which may be acceptable in some applications is forging by compressing joining region **52** of tubular section **50** in a heated tool of the desired shape.

[0026] In a preferred embodiment, inner tube **54** is comprised of PTFE (polytetrafluoroethylene). PTFE is a preferred material because it creates a smooth, low-friction surface for the passage of other devices through the catheter. Also in a preferred embodiment, support member **56** is a stainless steel wire, wound in a braided pattern around inner tube **54**. Those with skill in the art will appreciate that other embodiments of support member **56** are possible without deviating from the spirit and scope of the present invention. For example, support member **56** may be comprised of a woven polymer fabric. By way of a second example, support member **56** may be comprised of polymer fibers wound in a braided pattern.

[0027] In a preferred embodiment, outer tube **58** is comprised of polyether block amide (PEBA). Polyether block amide is commercially available from Atochem Polymers of Birdsboro, Pa. under the trade name PEBAX. Outer tube **58** may be fabricated using an extrusion process. In this process, molten PEBA is extruded onto the combined layers of inner tube **54** and support member **56**. When this process is used, the material of outer tube **58** fills any interstitial spaces in support member **56**.

[0028] It is to be understood that other manufacturing processes can be used without departing from the spirit and scope of the present invention. Outer tube **58** may also be comprised of other materials without departing from the

spirit of scope of this invention. Examples of materials which may be suitable in some applications include: polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC), polyurethane, and polytetrafluoroethylene (PTF).

[0029] As described previously, the material of distal tip **20** is preferably a relatively soft material. Distal tip **20** may be comprised of a material which is softer than the material of outer layer **56**. In a preferred embodiment, both distal tip **20** and outer layer **56** are comprised of polyether block amide (PEBA). However, in this preferred embodiment, distal tip **20** is comprised of a PEBA material with a lower durometer than that of outer layer **56**.

[0030] Those with skill in the art will appreciate that other embodiments of tubular section **50** are possible without deviating from the spirit or scope of the present invention. For example, tubular section **50** may include more or fewer component layers.

[0031] **FIG. 3** is an enlarged sectional view of an additional embodiment of a tubular section **50**. In the embodiment of **FIG. 3**, tubular section **50** includes a wall **250** which is comprised of a first material. Tubular section **50** also includes a joining region **52** having a plurality of ribs **60**. A variety of manufacturing methods may be used to form ribs **60** on joining region **52** of tubular section **50** including material forming processes and material removal processes. Examples of material removal processes which may be acceptable in some applications include turning on a lathe and centerless grinding. An example of a material forming process which may be acceptable in some applications is forging by compressing joining region **52** of tubular section **50** in a heated tool of the desired shape. Ribs **60** are preferably about 0.001 inches to about 0.006 inches in height relative to the reduced diameter longitudinal regions therebetween.

[0032] **FIG. 4** is a plan view of an assembly including a first tubular member **50** and a second tubular member **51**. Tubular members **50** and **51** include lumens **48** and **49**, respectively. In **FIG. 4, a** mandrel **100** has been positioned so that at least a portion of its length is disposed inside lumens **48**, **49** of tubular members **50**, **51**. Tubular member **50** includes bonding region **52** having a plurality of ribs **60**. Tubular member **51** includes a joining region **53**, which is a portion of the lumen wall over a selected length.

[0033] In **FIG. 4**, bonding region **52** of tubular member **50** has been inserted into bonding region **53** of tubular member **51**. In a preferred embodiment of tubular member **51**, the inner diameter of bonding region **53** is slightly flared to facilitate the insertion of bonding region **52** of tubular member **50**. This flared diameter may be created using a heat forming process. Alternately, bonding region **52** of tubular member **50** may be press fit into bonding region **53** of tubular member **51** without first creating a flare.

[0034] A method of bonding tubular members in accordance with the present embodiment may be described making reference to **FIG. 4**. A preferred method begins with the step of forming joining region **52** and ribs **60** in tubular member **50**. A variety of manufacturing methods may be used to form ribs **60** on tubular member **50** including material forming processes and material removal processes. Examples of material removal processes which may be acceptable in some applications include turning on a lathe and centerless grinding. An example of a material forming process which may be acceptable in some applications is forging by compressing joining region **52** of tubular member **50** in a heated tool of the desired shape.

[0035] A method in accordance with the present invention includes the step of positioning mandrel **100** so that at least a portion of its length is disposed inside lumen **48** of tubular member **50**. In a preferred method, this step takes place after the formation of joining region **52** and ribs **60**. Those of skill in the art will appreciate that the order of the steps in this method may be changed without deviating from the spirit and scope of the invention. For example, mandrel **100** may be positioned in lumen **48** of tubular member **50** prior to the formation of joining region **52** and ribs **60**. Alternately, mandrel **100** may be positioned in lumen **48** of tubular member **50** after joining region **52** of tubular member **50** has been inserted into joining region **53** of tubular member **51**.

[0036] In the next step of a preferred method, bonding region **52** of tubular member **50** is inserted into bonding region **53** of tubular member **51**. A preferred method in accordance with the invention includes the step of flaring the inner diameter of tubular member **51** proximate bonding region **53**. Bonding region **53** of tubular member **51** may be flared to facilitate the insertion of bonding region **52** of tubular member **50**. A number of methods may be used to flare tubular member **51** proximate bonding region **53**. In a method which may be suitable for some applications, the bonding region **53** of tubular member **51** is heated, then a mandrel is urged into lumen **49** of tubular member **51**. To facilitate the flaring process, a portion of the mandrel has a diameter larger than the diameter of lumen **49** of tubular member **51**. It should be noted that the mandrel may include steps and tapers. The distal end of tubular member **51** takes on the shape of the mandrel as a result of urging the mandrel into heated tubular member **51**.

[0037] After bonding region **52** of tubular member **50** is inserted into bonding region **53** of tubular member **51**, mandrel **100** will be positioned so that at least a portion of the length thereof is disposed inside both lumen **48** of tubular member **50** and lumen **49** of tubular member **51**.

[0038] Having thus assembled tubular members **50**, **51**, heat and pressure are applied to joining regions **52**, **53**. A number of methods may be used to heat joining regions **52**, **53** including convection, conduction and radiation. An example of heating with radiant energy is directing infrared energy from an infrared heat source at joining regions **52** and **53**. Infrared energy sources suitable for this process are commercially available from Research Incorporated of Minnetonka, Minn. A second example of heating with radiant energy is exposing the regions to be heated to radio frequency energy.

[0039] An example of heating with convection includes directing a flow of hot air from a hot air gun so that it impinges on joining regions **52** and **53**. Hot air guns suitable for this application are commercially available from Leister Elektro-Geratebau of Lucerne, Switzerland. A second example of heating with convection includes placing the portion being heated in a temperature chamber. Temperature chambers suitable for this process are commercially available from Thermotron Corporation of New Holland, Mich.

[0040] An example of heating with conduction is placing a heated tool in direct contact with the outside diameter of

joining region **53** and/or the inside diameter of joining region **52**. Suitable heated tools may be comprised of a number of materials including stainless steel. Electric heaters suitable for heating a heated tool are commercially available from Watlow Incorporated of St. Louis, Mo.

[**0041**] Pressure may be applied to joining regions **52**, **53** via a fluid under pressure or via a solid tool adapted to apply pressure to the outer diameter of joining region **53**. Pressure may be applied using a fluid by positioning joining regions **52**, **53** within a pressure vessel, then pressurizing the vessel with a fluid. In this example, the fluid could be air, water, alcohol, nitrogen gas, etc.

[**0042**] Having formed a bond, the assembly is then allowed to cool. The assembly may be submersed in a relatively cool fluid to speed cooling of the assembly. Examples of fluids which may be suitable for some applications include water and air. Relatively cool air may also be impinged onto the assembly. Cold air generators suitable for this purpose are commercially available from ITW Vortec of Cincinnati, Ohio and Exair Corporation of Cincinnati, Ohio.

[**0043**] After the catheter assembly has cooled, mandrel **100** may be removed from the lumen of the catheter assembly. In a preferred method, the outer surface of mandrel **100** includes polytetrafluoroethylene (PTFE). PTFE is preferred because it provides a substantially non-stick surface. This substantially non-stick surface aids in the removal of mandrel **100** from the lumen of the catheter assembly.

[**0044**] **FIG. 5** is a partial plan view illustrating joining regions **52**, **53** after the completion of the bonding process. In **FIG. 5** tubular member **51** is shown in cross-section and tubular member **50** is not. As seen in **FIG. 5**, the material of tubular member **51** has conformed to the shape of bonding area **52** of tubular member **50**. As a result of the joining process, joining region **53** of tubular member **51** includes a groove **62** corresponding to each rib **60** of tubular member **50**. The interlocking geometry of ribs **60** and grooves **62** increases the mechanical strength of the resulting joint. Also as a result of the joining process, a lap joint heat bond **70** has been formed between the inner diameter of tubular member **51** and the outer diameter of tubular member **50**. Also as a result of the joining process, a butt joint heat bond **72** has been formed between the proximal end of tubular member **51** and the distal end of tubular member **50**.

[**0045**] An additional method in accordance with the present invention is illustrated in **FIG. 6**. This method includes the step of positioning a sleeve **120** over both tubular members **50**, **51** in an area proximate joining area **53**. In a preferred embodiment, sleeve **120** is comprised of heat shrinkable polytetrafluoroethylene (PTFE). PTFE is preferred because it provides a substantially non-stick surface.

[**0046**] In a preferred embodiment, sleeve **120** is comprised of PTFE heat shrink tubing. Suitable PTFE heat shrink tubing is commercially available from Zeus Industries of Orangeburg, S.C. and Raychem Corporation of Menlo Park, Calif. When sleeve **120** is comprised of shrink tubing, the step of shrinking sleeve **120** may be included in a method in accordance with the present invention. A number of methods may be used to shrink sleeve **120** without departing from the spirit and scope of the present invention, including those steps previously described in conjunction with **FIG. 5**. In a preferred method, hot air is first impinged upon sleeve **120** causing it to shrink. Hot air guns suitable for this application are commercially available from Leister Elektro-Geratebau of Lucerne, Switzerland.

[**0047**] After sleeve **120** is disposed about tubular members **50**, **51**, heat and pressure are applied to joining regions **52**, **53** to form a bond. Having formed a bond, the assembly is then allowed to cool. The assembly may be submersed in a relatively cool fluid to speed cooling of the assembly. Examples of fluids which may be suitable for some applications include water and air. Relatively cool air may also be impinged onto the assembly. Cold air generators suitable for this purpose are commercially available from ITW Vortec of Cincinnati, Ohio and Exair Corporation of Cincinnati, Ohio. After the assembly has cooled, sleeve **120** is removed. This may be accomplished by scoring sleeve **120** with a cutting tool, and peeling it away from the catheter assembly.

[**0048**] The mandrel **100** is then removed from the lumen of the catheter assembly. In a preferred method, the outer surface of mandrel **100** includes polytetrafluoroethylene (PTFE). PTFE is preferred because it provides a substantially non-stick surface. This substantially non-stick surface aids in the removal of mandrel **100** from the lumen of the catheter assembly.

[**0049**] **FIG. 7** is a plan view of the proximal portion **16** of a catheter **10** in accordance with the present invention. Catheter **10** of **FIG. 7**, includes a tubular member **50** having a bonding region **52**. Catheter **10** also includes a strain relief **32** disposed about a portion of proximal portion **16** of catheter **10**. Catheter **10** also includes a hub **30** having a bonding region **200**, a coupling region **202**, and a strain relief region **32**. As shown in **FIG. 7**, bonding region **200** of hub **30** is generally disposed about and bonded to bonding region **52** of tubular member **50**.

[**0050**] Bonding region **52** of tubular member **50** includes a plurality of ribs **60**. Bonding region **200** of hub **30** includes a plurality of grooves **204** corresponding to ribs **60** of tubular member **50**. As shown in **FIG. 7**, ribs **60** of tubular member **50** are generally disposed in grooves **204** of hub **30**. The interlocking geometry of ribs **60** and grooves **204** increases the mechanical strength of the resulting joint. Coupling region **202** of hub **30** is adapted to form a mating connection with other devices. Specifically, coupling region **202** is adapted to form a connection which places another device in fluid communication with a lumen **206** of hub **30**. In one embodiment of the present invention, coupling region **202** includes a leur fitting.

[**0051**] A method of creating a hub bonded to a tubular member in accordance with the present invention may be described making reference to **FIG. 7**. A preferred method, begins with the step of forming ribs **60** in joining region **52** of tubular member **50**. A variety of manufacturing methods may be used to form ribs **60** on tubular section **60** including material forming processes and material removal processes. Examples of material removal processes which may be acceptable in some applications include turning on a lathe and centerless grinding. An example of a material forming process which may be acceptable in some applications is forging ribs by compressing joining region **52** of tubular member **50** in a heated tool of the desired shape.

[**0052**] The proximal portion of tubular member **50** including joining region **52** is then positioned inside a mold cavity

and molten plastic is injected into the mold. The molten plastic surrounds joining region **52** of tubular member **50** forming grooves **204** corresponding to ribs **60**. The molten plastic is then allowed to cool and solidify forming hub **30**. Once hub **30** has been formed, it is removed from the tool. The interlocking geometry of ribs **60** and grooves **204** increases the mechanical strength of the resulting joint.

[**0053**] Having thus described the preferred embodiments of the present invention, those of skill in the art will readily appreciate that yet other embodiments may be made and used within the scope of the claims hereto attached.

[**0054**] Numerous advantages of the invention covered by this document have been set forth in the foregoing description. It will be understood, however, that this disclosure is, in many respects, only illustrative. Changes may be made in details, particularly in matters of shape, size, and arrangement of parts without exceeding the scope of the invention. The invention's scope is, of course, defined in the language in which the appended claims are expressed.

What is claimed is:

1. A method of bonding a first tubular member to a second tubular member to form a catheter shaft, the method comprising the steps of:

providing a first tubular member including a distal end, a proximal end, and a lumen extending between the distal end and the proximal end thereof;

providing a second tubular member including a distal end, a proximal end, and a lumen extending between the distal end and the proximal end thereof;

the second tubular member including bonding region proximate the proximal end thereof;

forming a bonding region in the first tubular member proximate the distal end thereof; the bonding region including at least one rib and at least one area of generally reduced diameter;

inserting a mandrel into the lumen of the first tubular member proximate the distal end thereof;

inserting the distal end of the first tubular member into the lumen of the second tubular member so that the bonding region of the second tubular member is disposed about the joining region of the first tubular member;

heating the joining region of the second tubular member, wherein a bond is formed between the bonding region of the second tubular member and the bonding region of the first tubular member; and

removing the mandrel from the lumen of the first tubular member.

2. The method of claim 1, further including the steps of providing a sleeve having a lumen and positioning the sleeve so that it overlays the bonding region of the second tubular member.

3. The method of claim 1, further including the steps of providing a sleeve comprised of shrink tubing, positioning the sleeve so that it overlays the bonding region of the second tubular member, and heating the sleeve so that it shrinks.

4. The method of claim 1, further including the step of cooling the joining portion of the second tubular member.

5. The method of claim 1, further including the step of heating the joining region of the first tubular member.

6. The method of claim 1, further including the step of applying pressure to an outer surface of the joining portion of the second tubular member.

7. The method of claim 1, further including the step of flaring the proximal end of the second tubular member.

8. The method of claim 1, wherein the first tubular member is comprised of a thermoplastic material.

9. The method of claim 1, wherein the second tubular member is comprised of a thermoplastic material.

10. The method of claim 1, wherein the first tubular member is comprised of polyether block amide.

11. The method of claim 1, wherein an outer diameter of the mandrel is substantially equal to a diameter of the lumen of the first tubular member.

12. The method of claim 1, wherein a diameter of the lumen of the second tubular member is substantially equal to a diameter of the lumen of the first tubular member.

13. The method of claim 1, wherein an outer diameter of the first tubular member is substantially equal to an outer diameter of the second tubular member after the second tubular member has been bonded to the first tubular member.

14. The method of claim 1, wherein the step of forming the joining region of the first tubular member includes removing material from the first tubular member.

15. A method of bonding a first tubular member to a second tubular member to form a catheter shaft, the method comprising the steps of:

providing a first tubular member including a distal end, a proximal end, and a lumen extending between the distal end and the proximal end thereof;

forming a joining region proximate the distal end of the first tubular member, the joining region having an outer diameter generally less than the outer diameters of the first tubular member and at least one rib having an outer diameter greater than the basic diameter of the joining region;

inserting a mandrel into the lumen of the first tubular member;

providing a second tubular member including a distal end, a proximal end, and a lumen extending between the distal end and the proximal end thereof; the second tubular member including bonding region proximate the proximal end thereof;

inserting the distal end of the first tubular member into the lumen of the second tubular member so that the second tubular member is disposed about the joining portion of the first tubular member;

placing a sleeve over the assembly;

heating the joining portion of the first tubular member and the second tubular member; and

removing the mandrel from the lumen of the first tubular member.

16. The method of claim 15, wherein the step of forming the joining region includes removing material from the first tubular member.

17. The method of claim 15, wherein the step of forming the joining region includes deforming the first tubular member.

18. The method of claim 15, further including the step of cooling the joining portion of the second tubular member.

19. The method of claim 15, further including the step of applying pressure to the joining portion of the second tubular member.

20. The method of claim 15, further including the step of positioning a sleeve so that it surrounds the joining region of the second tubular member.

21. The method of claim 15, wherein the first tubular member is comprised of a thermoplastic material.

22. The method of claim 15, wherein the second tubular member is comprised of a thermoplastic material.

23. The method of claim 15, wherein the first tubular member is comprised of polyether block amide.

24. A method of bonding a first tubular member to a second tubular member to form a catheter shaft, the method comprising the steps of:

providing a first tubular member including a distal end, a proximal end, and a lumen extending between the distal end and the proximal end thereof;

providing a second tubular member including a distal end, a proximal end, and a lumen extending between the distal end and the proximal end thereof;

the second tubular member including bonding region proximate the proximal end thereof;

providing a shrink tube sleeve;

forming a bonding region in the first tubular member proximate the distal end thereof; the bonding region including at least one rib and at least one area of generally reduced diameter;

inserting a mandrel into the lumen of the first tubular member proximate the distal end thereof;

inserting the distal end of the first tubular member into the lumen of the second tubular member so that the bonding region of the second tubular member is disposed about the joining region of the first tubular member;

positioning the shrink tube sleeve so that it overlays the joining region of the second tubular member;

applying pressure and heat to an outer surface of the joining portion of the second tubular member, wherein a bond is formed between the bonding region of the second tubular member and the bonding region of the first tubular member;

cooling the joining region of the second tubular member; and

removing the mandrel from the lumen of the first tubular member.

25. A method of bonding a hub to a catheter shaft, the method comprising the steps of

providing a tubular member including a distal end, a proximal portion, a proximal end, and a lumen extending between the distal end and the proximal end thereof;

forming a bonding region on the tubular member proximate the proximal end thereof; the bonding region including at least one rib and at least one area of generally reduced diameter;

positioning the proximal portion of the tubular member inside the cavity of a molding tool;

injecting molten plastic into the cavity of the molding tool; and

allowing the molten plastic to cool.

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